"Energy of Röntgen and Becquerel Rays and the Energy required to produce an Ion in Gases."

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(Abstract.)

The primary object of the investigations described in the paper was the determination of the energy required to produce a gaseous ion when X rays pass through a gas, and to deduce from the result the amount of energy radiated out into the gas by uranium, thorium, and the other radio-active substances.

In order to determine this "ionic energy" it has been necessary to accurately measure the heating effect of X rays and the absorption of Röntgen radiation in passing through a gas.

The coefficient of transformation of a fluorescent screen excited by X rays as a source of light has also been investigated, and a simple practical method of expressing the intensity of Röntgen radiation in absolute measure has been explained.

The method adopted to determine the ionic energy was briefly as follows:—

The maximum current between two electrodes produced by the ionization of a known volume of the gas by the rays was determined.

In order to ionize the gas energy has to be absorbed, and the intensity of the radiation falls off more rapidly than the law of inverse squares. Assuming that the energy of the radiation absorbed in the gas is expended in the production of ions, then, knowing the coefficient of absorption of the rays in the gas, the total current produced by the complete absorption of the whole radiation given out by the bulb into the gas can be deduced.

Let i = maximum current produced by the total ionization of the gas by the rays,

n = number of ions produced,

ϵ = charge on an ion.

Then $i = n\epsilon$.

Let H = heating effect due to the rays when absorbed in a metal,

E = total energy of the rays in ergs,

Then E = JH, where J = Joule's equivalent.

If W = average energy required to produce an ion, then

$$nW = E = J.H,$$

$$\therefore W = \frac{JH}{n} = \frac{JH\epsilon}{i}.$$

The values of H and i are experimentally determined, and, assuming the value of ϵ, namely, $6 \cdot 5 \times 10^{-10}$ electrostatic unit, determined by J. J. Thomson, the value of W is found in absolute measure.

In the course of the investigation the following subjects have been considered :—

(1) Measurement of the heating effect of X rays.

(2) Efficiency of a fluorescent screen excited by X rays as a source of light.

(3) Absorption of X rays in gases at different pressures.

(4) Determination of the energy required to produce an ion in air and other gases, including deductions on—

(*a*) Distance between the charges of ions in a molecule.
(*b*) Minimum potential difference required to produce a spark.

(5) Energy of Becquerel rays and emission of energy by radio-active substances.

Heating Effect of X Rays.

An automatic focus tube was employed, excited by a large induction coil with a special form of Wehneldt interrupter giving fifty-seven breaks per second. The bulb gave out intense rays of a very penetrating character.

The heating effect was measured by determining the variation of resistance of a special platinum bolometer when the rays fell upon it. A platinum strip, about 3 metres in length, 0·5 cm. wide, and 0·003 cm. thick, was wound on a light mica frame 10 cm. square. Two such "grids," as similar as possible, were constructed, and formed the two arms of a Wheatstone bridge. A balance was obtained for a momentary pressing of the battery key, using a sensitive galvanometer. The rays were then turned on for 30 or 45 seconds, and the deflection from zero determined immediately after the rays were stopped.

In order to measure the heating effect, a current was sent for the same time as the rays acted through the grid, and its value adjusted until the deflection due to the heating of the grid was the same as for the rays. When this is the case the heat supplied per second to the grid by the rays is equal to the heat supplied per second by the current.

Thus, heating effect of rays per second $= 0 \cdot 24 i^2$ R calorie, where

$i =$ current through the grid of resistance R.

The grids were enclosed in a lead vessel with an aluminium window to let in the rays. The whole was surrounded by a felt covering, and several aluminium plates intervened between the bulb and the grid, so that any heating effect, except that due to the rays, was completely eliminated.

About 0·55 of the energy of the incident rays was absorbed in the grid. Some of the energy of the rays was used up in exciting secondary radiation at the surface of the platinum grid, but the amount was not large, and was neglected in comparison with the total energy of the rays.

The rate of supply of heat to the grid area 92·2 sq. cm. at a distance of 26 cm. from the source of rays was

0·00014 gramme-calorie per second.

The total energy of the rays given out from the front surface of the platinum antikathode (omitting absorption of rays in the glass of bulb, in air and screens) was

0·011 gramme-calorie per second,

or 0·046 watt.

The number of discharges per second was 57, and assuming 10^{-5} second* as the average duration of the rays during each discharge, the maximum rate of emission of energy from the bulb

= 19·5 calories per second.

The heating effect of the sun's rays falling normally on 1 sq. cm. of surface = 0·035 calorie per second. The maximum rate of emission of energy from an X-ray bulb is thus 560 times greater than the energy of the sun's rays at the surface of the earth.

Some experiments were made on the heating effect of the rays, using a thermopile, but it was found to be a very unsuitable instrument for such a determination.

Efficiency of a Fluorescent Screen.

Photometric comparisons were made of the light from a fluorescent screen with that of the standard Hefner-Alteneck amyl lamp, using a Lummer-Brodhun prism. With a screen of platinocyanide of barium

$$\frac{\text{Intensity of light from screen}}{\text{Intensity of light from amyl lamp}} = 0{\cdot}0206.$$

Tumlirz† has shown that the energy of the visible light from an amyl lamp falling normally on 1 sq. cm. surface at unit distance

= 0·00361 gramme-calorie per second.

For X rays of the same intensity as were used in the photometric measurements, the energy under the same conditions

= 0·0023 calorie,

* Trouton, 'Brit. Assoc. Report,' 1896.

† 'Wied. Annal.,' vol. 38, p. 640.

or the rate of emission of energy per second as visible light from the Hefner lamp is nearly twice the rate of emission of energy from the X-ray tube. 0·73 of the energy of the rays was absorbed in the screen.

The efficiency of the transformation of X rays into visible light by the screen (compared with the Hefner lamp)

$$= 0{\cdot}044 \quad \text{or} \quad 4{\cdot}4 \text{ per cent.}$$

Assuming this transformation factor for a fluorescent screen, two simple photometric measurements are required to express the energy of any bulb in absolute measure. The light from a fluorescent screen is first compared with the standard Hefner lamp. The absorption of the rays in the screen is determined by placing a piece of the screen in the path of the rays.

Let ρ = ratio of intensities of light from bulb and lamp,

ρ_1 = ratio of transmitted to incident radiation on the screen.

Then it is shown that the intensity in absolute measure

$$= \frac{0{\cdot}082\rho}{1 - \rho_1} \text{ gramme-calorie per second.}$$

The absorption in the cardboard of the screen is supposed to be negligible, but if necessary can be readily allowed for.

Absorption of X Rays in Gases.

A null method was employed, as the absorption of the rays in air at atmospheric pressure was small. The rays passed through two long brass tubes with aluminium ends, and the current produced by the rays, after passing through one tube, was balanced against the current due to the other. On exhausting one tube the electrometer balance was disturbed. From measurements of the deflection per second from the balance and the deflection per second due to the rays after passing through one tube, the absorption can be calculated. The mean value of the coefficient of absorption of the rays in air at atmospheric pressure was found to be

$$0{\cdot}000279,$$

or the rays would pass through 24·7 metres before absorption reduced the intensity of the radiation to one-half.

The absorption was found to be proportional to the pressure from a half atmosphere to three atmospheres.

The coefficient of absorption in carbonic acid gas was found to be 1·59 times the absorption in air.

Energy required to produce an Ion.

The current produced when a given volume of the gas was ionized by X rays was determined by means of an electrometer. In order to get rid of the secondary radiations set up when X rays strike on a conductor, the rays passed between two charged parallel plates without striking them. A guard-ring method was employed to ensure uniformity of the electric field.

The value of the ionic energy was deduced from the determination of the current, heating effect, and absorption of the rays. The mean value of the energy required to produce an ion in air at atmospheric pressure and temperature was found to be

$$1{\cdot}90 \times 10^{-10} \text{ erg.}$$

This value is much greater than the energy required to produce hydrogen and oxygen ions in the decomposition of water.

The ionic energy of air was found to be approximately the same from pressures of one-half to three atmospheres.

The method of determining the ionic energy for other gases is described, and the evidence that the "ionic energy" is the same for all gases is discussed.

Distance between the Charges of the Ions in a Molecule.

On the assumption that the energy absorbed in producing an ion is due to the work done in separating the ions against the forces of their electrical attraction, it can be shown that the mean distance between the charges of the ions in the molecule is

$$1{\cdot}1 \times 10^{-9} \text{ cm.}$$

This is only $\frac{1}{30}$ of the probable diameter of the atom. This result is in accordance with the view recently advanced by J. J. Thomson, that ionization is produced by the removal of a negative ion from the molecule, and that the negative ion is only a small fraction of the mass of an atom.

Minimum Potential required to produce a Spark.

If the production of ions is necessary before a spark can pass, it can readily be deduced from the value of ionic energy that a spark cannot pass for a potential difference less than 175 volts. Experiments have shown that the minimum value is over 300 volts. The theoretical value is of the same order, but from the complexity of the phenomena a very close agreement could not be expected.

Emission of Energy from Radio-active Substances.

The velocity of the ions produced by Röntgen and uranium radiation in air has been shown to be the same. The ions are thus probably the same, and it is a reasonable assumption that the same energy is required in both cases to produce them. On this assumption the energy radiated by the radio-active substances can be determined.

The radio-active material was spread over a known area and the maximum current produced between the parallel plates determined. The number of ions produced, and consequently the energy to produce them, can be calculated.

For a thick layer of uranium oxide (3·6 grammes spread over a surface of 38 cm.) the energy radiated into the gas for 1 sq. cm. of the surface is

$$10^{-11} \text{ calorie per second.}$$

This amount of energy would suffice to raise 1 c.c. of water 1° C. in 3000 years, assuming no loss of heat by radiation. From observations on the current due to a very thin layer of uranium oxide it is shown that the energy radiated into the gas is not less than 0·032 calorie per year for every gramme of the substance.

The energy radiated from thorium and radium is also considered, and the presence of the rays from radium deflected by a magnet is taken into account.

In the case of radium, which is 100,000 times more radio-active than uranium, the emission of energy per gramme of the substance is not less than 3000 calories per year.

"On Expressed Yeast-cell Plasma (Buchner's 'Zymase')." By

ALLAN MACFADYEN, M.D., G. HARRIS MORRIS, Ph.D., and SYDNEY ROWLAND, M.A. Communicated by Sir HENRY E. ROSCOE, F.R.S. Received June 19—Read June 21, 1900.

(First communication.)

Introduction.—In 1897 a communication was published by Professor E. Buchner* in which he described a method by means of which he claimed to have isolated for the first time the active alcoholic ferment from the yeast-cell and to have demonstrated its action upon fermentable sugars. Since then Buchner, mainly in conjunction with Rapp, has from time to time given an account of his further investigations in this direction, and these investigations are still in progress.

* 'Berichte d. deutsch. Chem. Ges.,' 1897, p. 117. *Vide* also succeeding papers, 1897—1900, *ibid.*